

# Advanced X-Ray Sources Ensure Safe Environments

## Originating Technology/NASA Contribution

Successfully sustaining life in space requires closely monitoring the environment to ensure the health of the crew. Astronauts can be more sensitive to air pollutants because of the closed environment, and pollutants are magnified in space exploration because the astronauts' exposure is continuous. Sources of physical, chemical, and microbiological contaminants include humans and other organisms, food, cabin surface materials, and experiment devices.

One hazard is the off-gassing of vapors from plastics and other inorganic materials aboard the vehicle, vividly illustrated by Skylab—in 1973, NASA scientists identified 107 volatile organic compounds in the air inside the Skylab space station. All synthetic materials exude low-level gasses, known as off-gassing; when these chemicals are trapped in a closed environment, as was the case with the Skylab, the inhabitants may become ill. To avoid this, air sampling systems on the International Space Station (ISS) periodically check the air for potential hazards. Advanced, high-efficiency particulate air filters and periodic filter cleanings have been successful in keeping harmful vapors out of the air. Other significant contaminants that pose hazards to the crew are microbial growth, both bacterial and fungal; air, water, and surface sampling by the crew in conjunction with periodic cleaning keep the microbial levels on the ISS in check.

To monitor microbial levels, crew members use devices called grab sample containers, dual absorbent tubes, and swabs to collect station air, water, and surface samples and send them to Earth for detailed analysis and identification every 6 months. This data provides controllers on Earth detailed information about the type of microbial contaminants on board the ISS. The controllers can then give additional direction to the crew on sanitation if increased microbial growth is identified.

Missions to the Moon and Mars will increase the length of time that astronauts live and work in closed

environments. To complete future long-duration missions, the crews must remain healthy in these closed environments; hence, future spacecraft must provide even more advanced sensors to monitor environmental health and accurately determine and control the physical, chemical, and biological environment of the crew living areas and their environmental control systems.

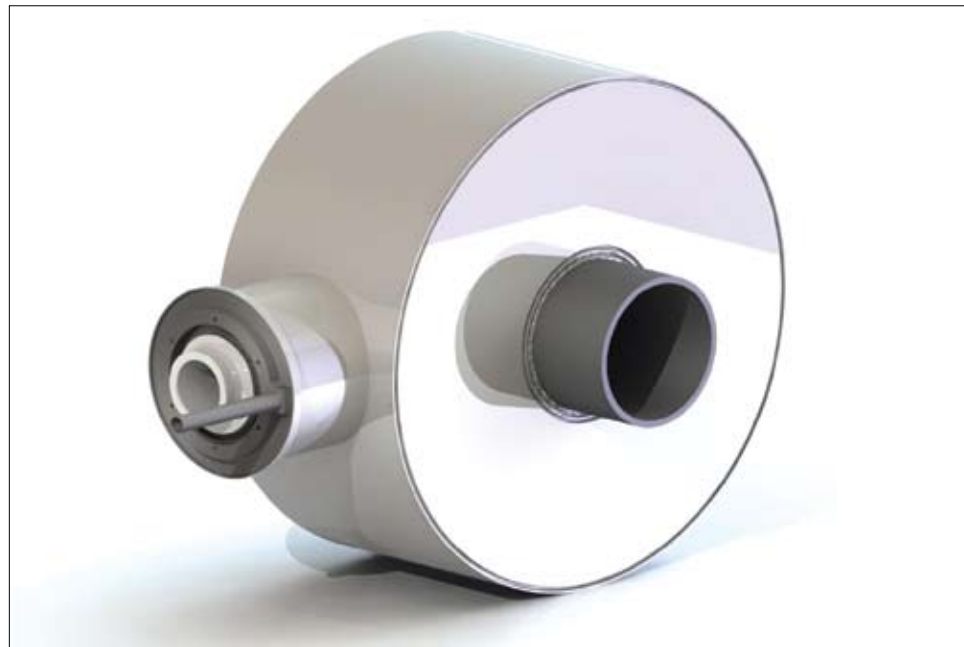
## Partnership

Ames Research Center awarded inXitu Inc. (formerly Microwave Power Technology), of Mountain View, California, a **Small Business Innovation Research (SBIR)** contract to develop a new design of electron optics for forming and focusing electron beams that is applicable to a broad class of vacuum electron devices.

This project resulted in a compact and rugged X-ray tube with a carbon nanotube (CNT) cold cathode with a circular electron beam that is focused to a diameter of

less than 80 microns. The performance, durability, and operating life of CNT cathodes was enhanced by inXitu working in cooperation with Ames; Oxford Instruments, of Scotts Valley, California; and Xintek Inc., of Research Triangle Park, North Carolina; among others. inXitu constructed an automated system for screening up to 10 CNT cathodes at once. Performance data from these tests helped CNT cathode researchers and developers improve tolerance to device processing, uniformity, and stability of performance within a given lot, enhancing performance of electron beam sources and ionizers in addition to other classes of X-ray tubes. This technology provides:

- Inherently rugged and more efficient X-ray sources for material analysis
- A miniature and rugged X-ray source for smaller rovers on future missions



The electron beam source can be scaled to fit any duct size and the flanges adapted to mate with existing systems. Reactions with the electron beam in the duct section destroy or neutralize contaminants entering via the airstream.

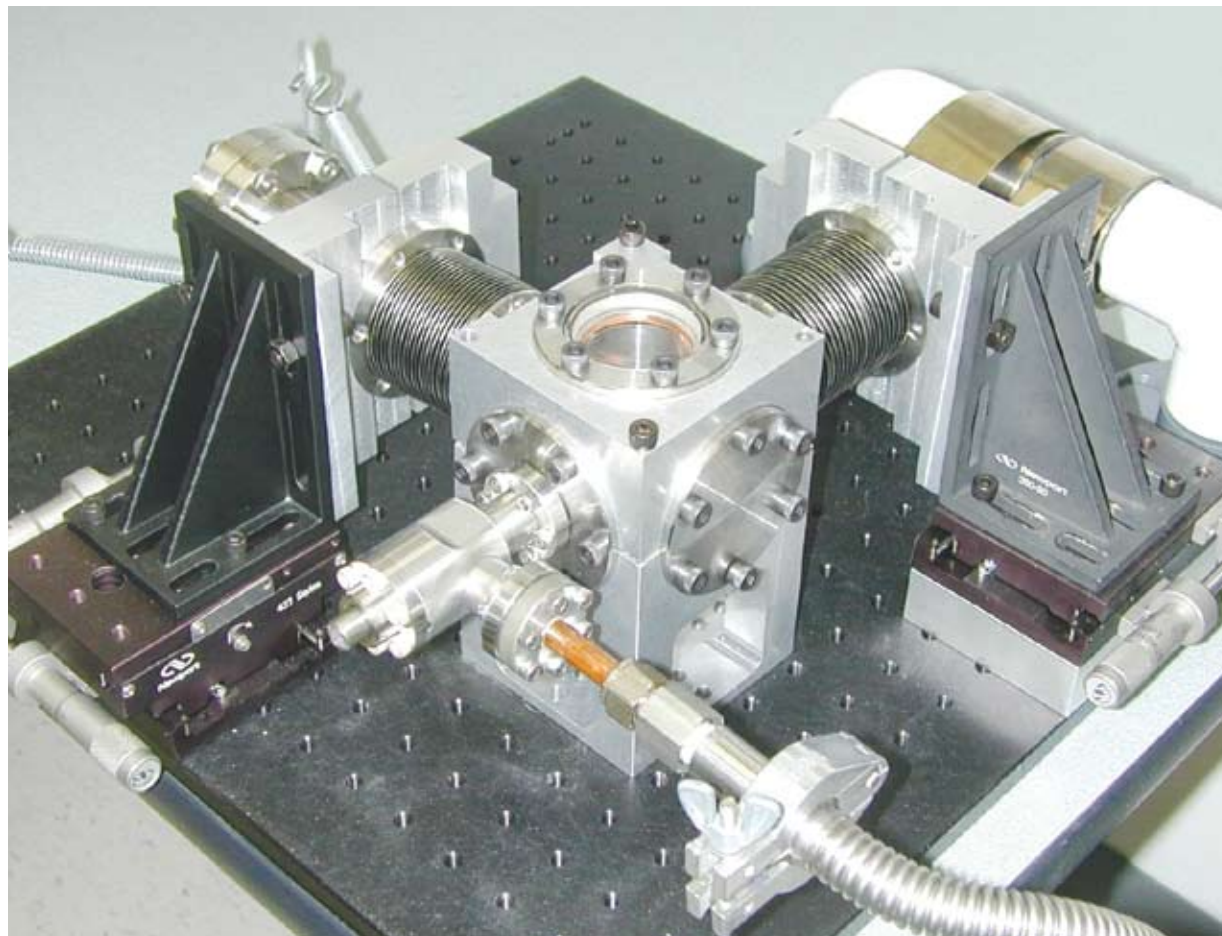
- Compact electron beam sources to reduce undesirable emissions from small, widely distributed pollution sources and remediation of polluted sites
- Large area emitters for new X-ray sources in future baggage scanning systems

Researchers derived a mathematical distribution function for the beam with a purpose-built electron beam analyzer, which characterized the unique behavior of electron beams emitted from CNT cathodes. A boundary element computer incorporated the distribution function code to design the electron optics, with an electrostatically focused electron gun and magnetic lens to focus the electron. The final X-ray tube consists of rugged metal ceramic construction welded into a 2-inch-diameter package along with a 40 kV power supply. This design forms a hermetic package that can withstand severe environmental stresses encountered during launch, landing, and operation in space.

NASA will apply this technology in versatile X-ray instruments capable of operating in both a fluorescence or diffraction mode for in situ analysis of rocks and soils of the solid bodies in the solar system to determine their atomic constituents and mineralogy. Other applications of this technology include purifying air in space and Moon base stations, eliminating toxic products and biological toxins in aircraft, enhancing chemical reactions in space-based manufacturing, and sterilization of material to be returned to Earth or taken to space from Earth. inXitu was awarded a Phase III SBIR contract in 2006 to continue this work.

## Product Outcome

Oxford's X-ray Technology Group provides laboratory space and production support for continuing development and commercialization of advanced CNT-based vacuum sources. The company produced Eclipse 1 and Eclipse 2 X-ray sources from inXitu's prototype that was used in hand-held and portable fluorescence spectrometers



The electron beam analyzer was designed to characterize the emission properties of carbon nanotube cathodes.

for in situ analysis of materials and surfaces. The Eclipse 2 X-ray tube was applied in equipment for monitoring paper coating and other high-speed processes.

Next-generation baggage and cargo screening systems employ CNT cold cathode X-ray sources, promising increased throughput, reduced false alarm rates, reduced power consumption, reduced heat load, reduced size and weight, and improved ruggedness and responsiveness

over existing thermionic X-ray sources. Additional commercial applications include air purification; odor elimination; non-burning destruction of evaporated hydrocarbons from fuel tanks and painting operations; soil and groundwater remediation; flue gas cleaning; and chemical reaction enhancements, such as increasing fuel efficiency and reducing ink drying speed, as well as surface sterilization. ❖